Increase of capacity on the Shinkansen high-speed line using virtual coupling

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Overview

- Next Generation Train project
- Virtual coupling
- Simulation tool
- Shinkansen scenarios

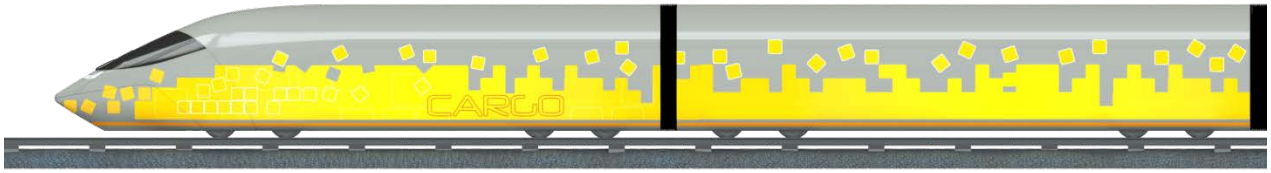
Next Generation Train project

Since 2007, 11 DLR Institutes, current phase until 2018

- Ultra-high-speed train (400 km/h, 202m, 800 seats, double-deck, 16 MW)
  NGT HST

- High-speed regional train (230 km/h, 120m, 480 seats, double deck)
  NGT LINK

- Ultra-high-speed Cargo train (400 km/h, currently in design process)
  NGT CARGO



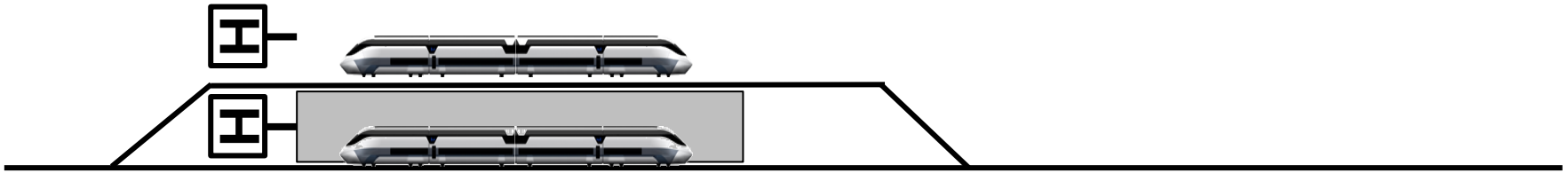
Introduction to virtual coupling

- General idea is the coupling and uncoupling of trains on the move, not only during the stop at the station
- Coupling on the move → every train part needs its own propulsion and energy supply
- Virtual coupling has benefits compared to mechanical coupling:
  - No mechanical couplers needed
  - Avoidance of problems with mechanical couplers
- Switch problem:
  - Switches can fail
  - The train has to able to stop in front of a switch
  - Coupling and dividing train parts have to keep the absolute braking distance ahead of switches
  - The operational benefit of coupling on the move gets lost
- Two general scenarios:
  - Use of conventional switches
  - Use of (not invented) “passive” switches, which can always be passed safely

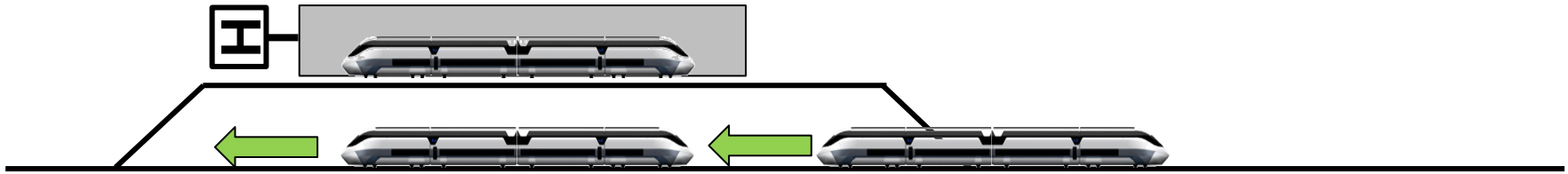
Scenario summary I
Conventional switches

Slip Coaching train is split up – the last wagons stop at platform

Doubling Scenario – Coupling the train after departure



Double overtake Scenario - Being overtaken by two trains

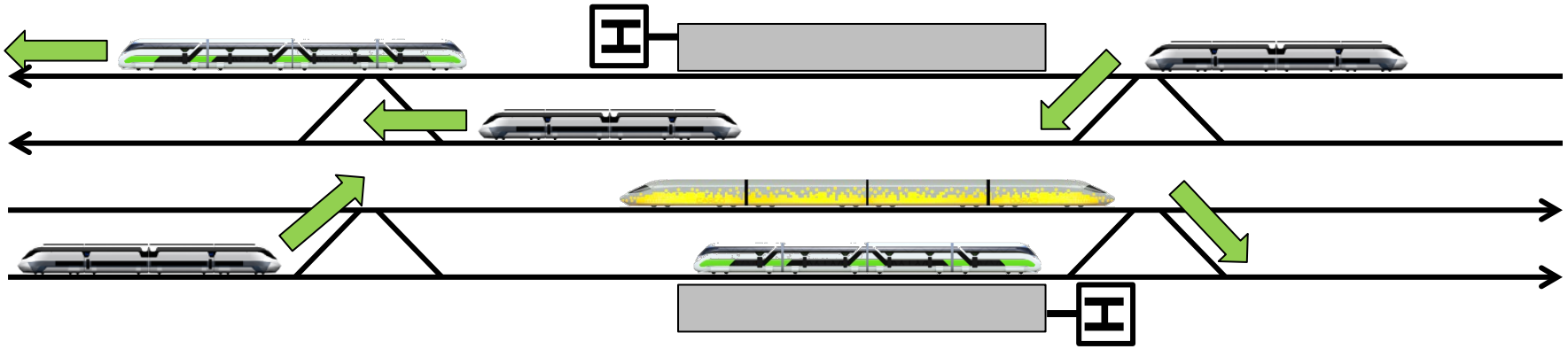


Scenario summary II

(Not invented) Passive switches

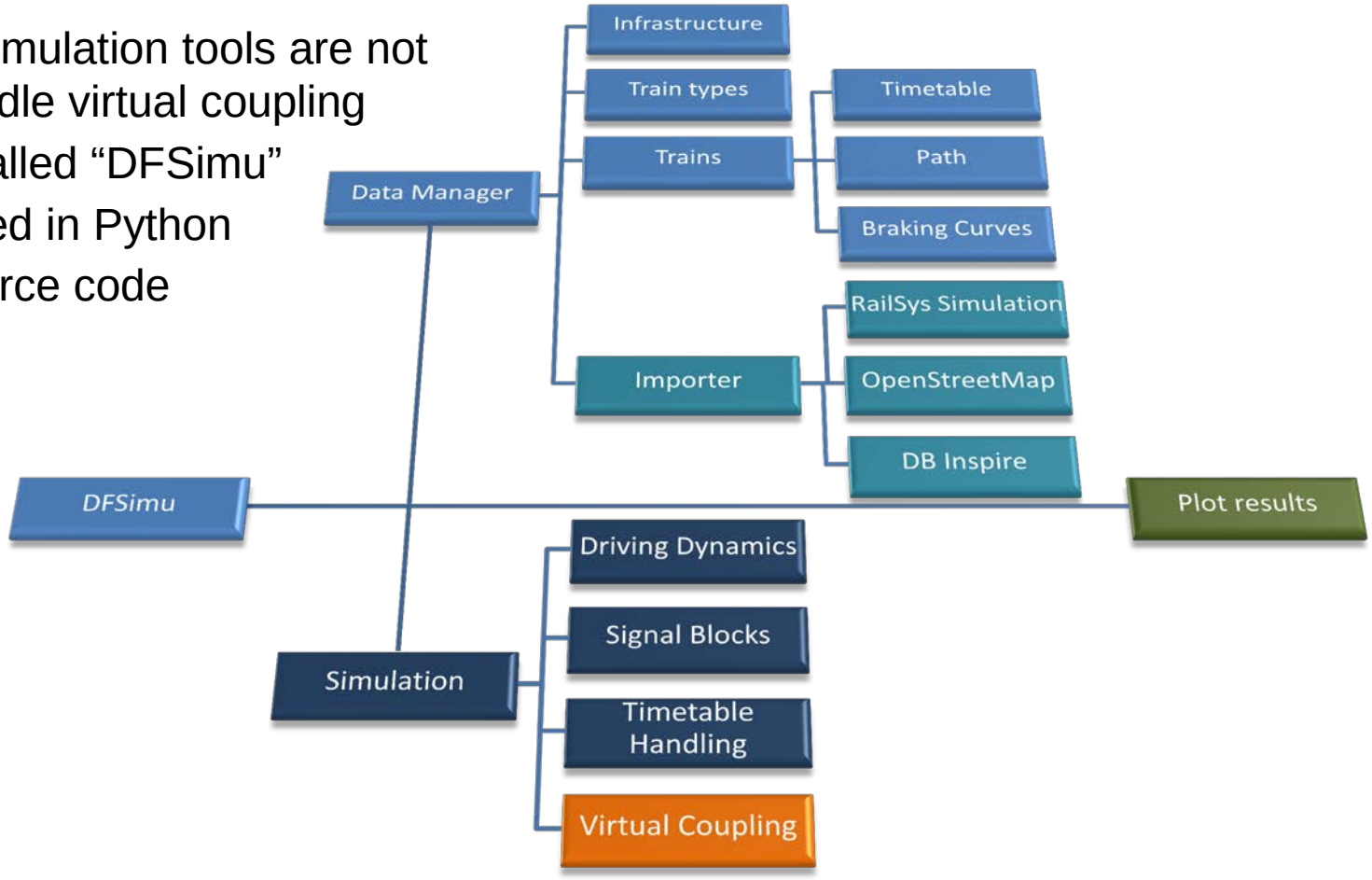
Coupling and splitting at junctions

Freeway Scenario – Dynamic overtaking on two tracks in each direction



Simulation environment

- Available simulation tools are not able to handle virtual coupling
- New tool called “DFSimu”
- Implemented in Python
- 500 kB source code

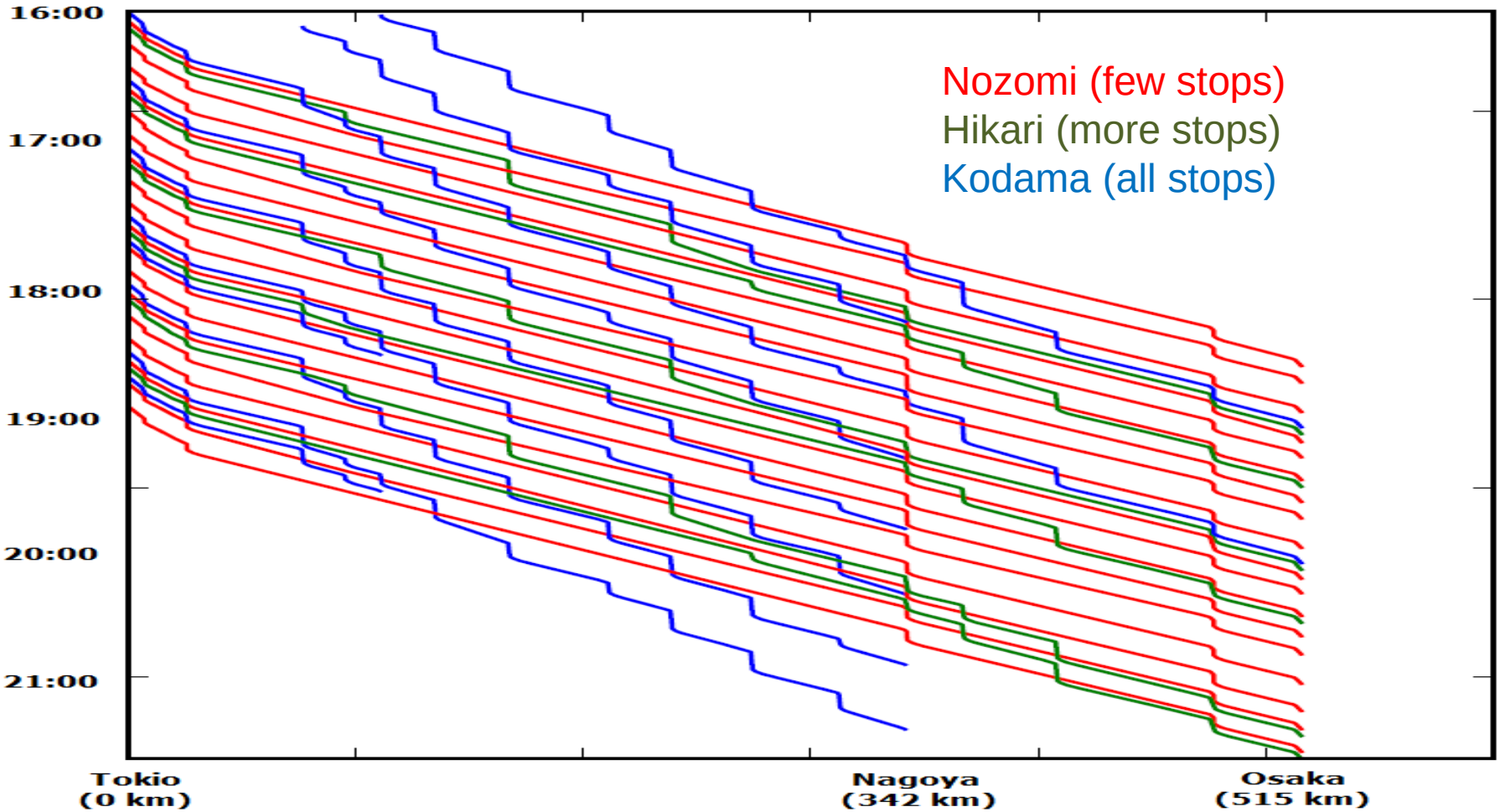


„Shinkansen“ scenario Tokaido line Tokio - Osaka

Pictures: Wikipedia

- Tokaido line is one of the most heavily used high-speed lines of the world
- Dense and punctual train traffic
- Need for more capacity
- Simulation with Shinkansen 700 type train (405m, 708t, 270 km/h, 1323 seats)

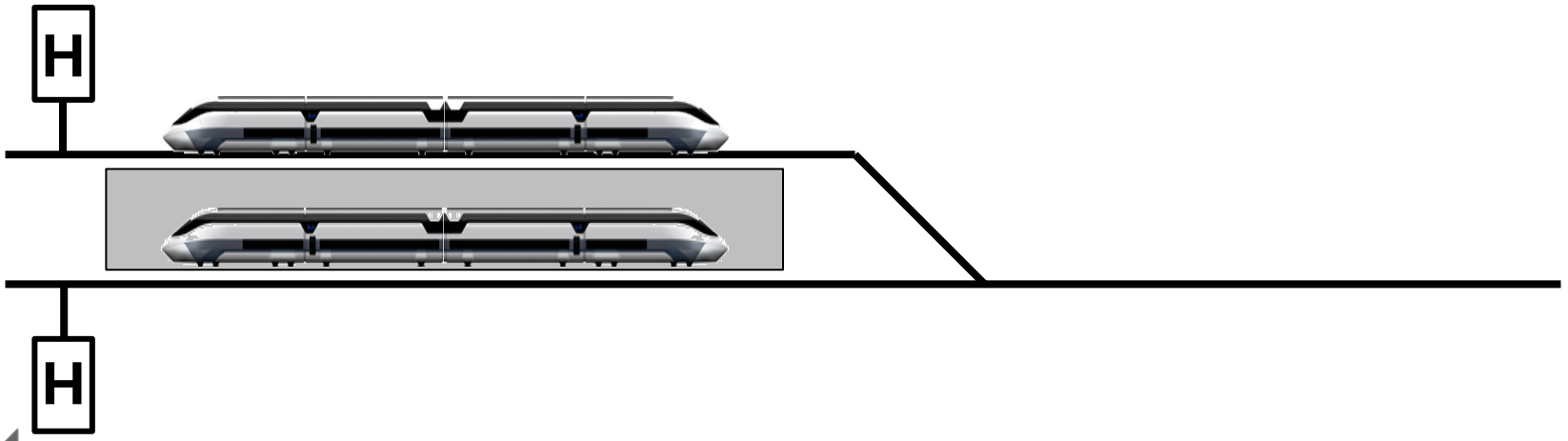
Graphical timetable of the afternoon outbound traffic from Tokio to Osaka



Shinkansen scenario 1: Doubling the Nozomi trains

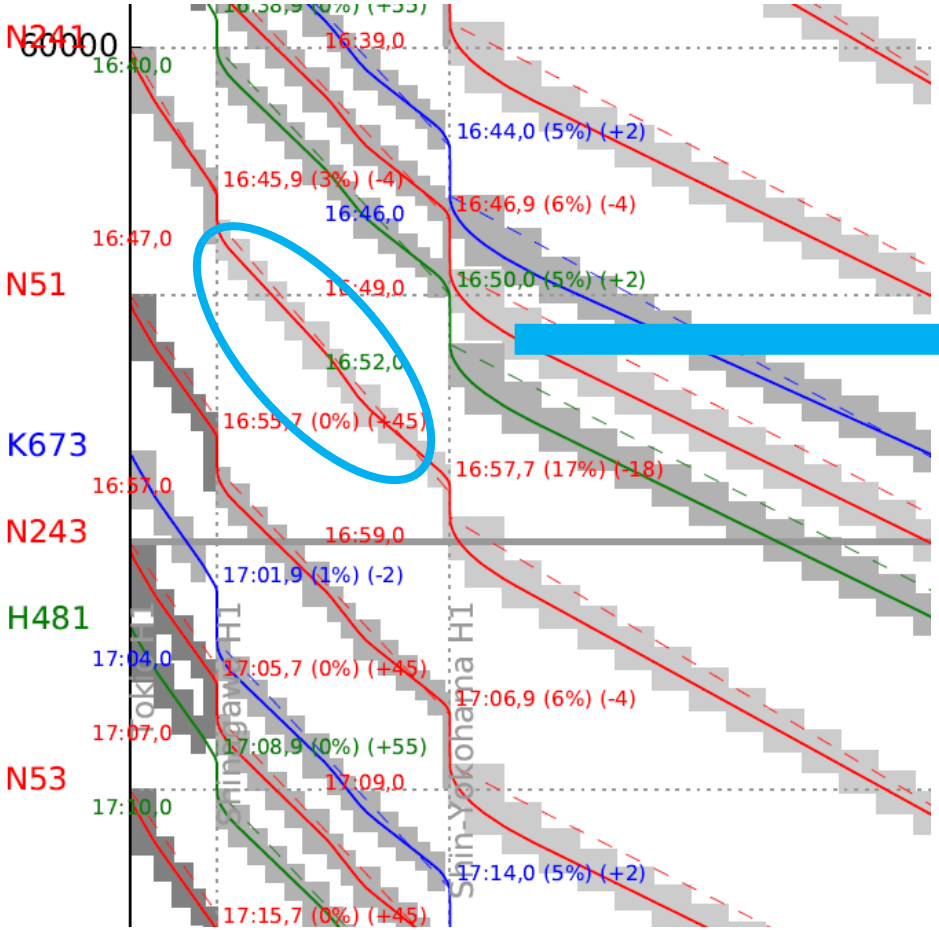
- Doubling of the fast Nozomi trains
- Leading train starts, following train is waiting until first common switch is cleared
- At the next station the following train keeps the braking distance to the dividing switch
- Using the fact, that the speed near stops is slower

→ Effect: Higher capacity (400 meters twice)

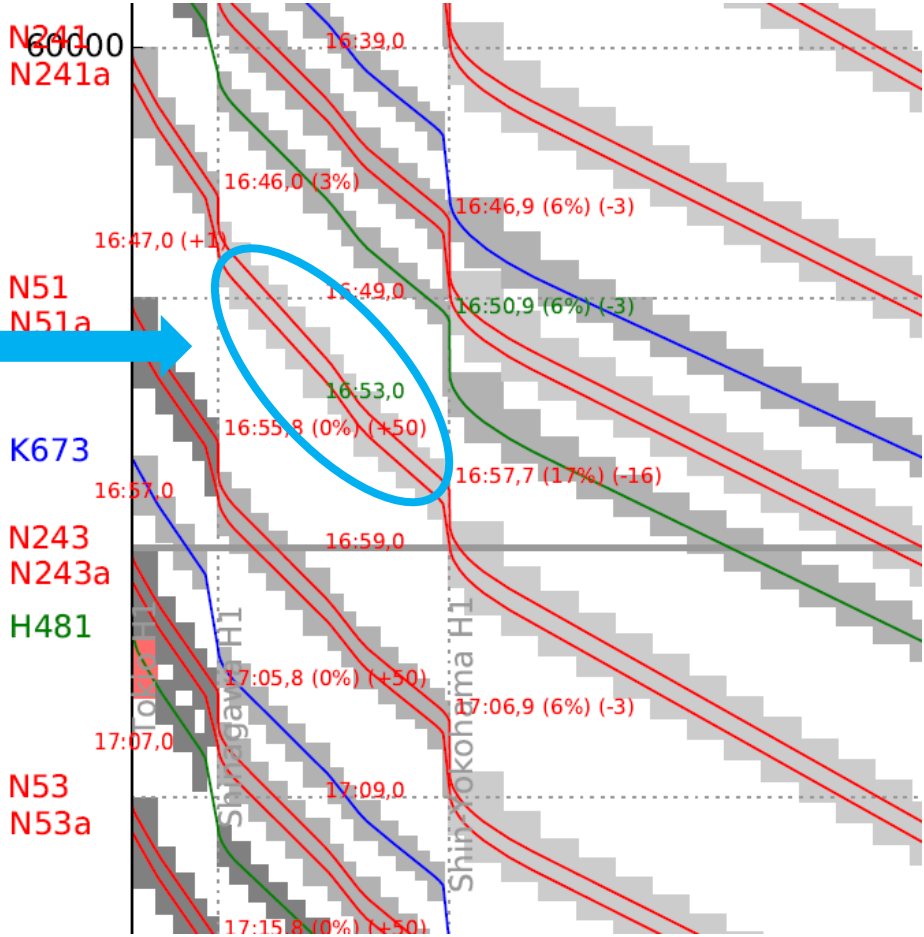


Shinkansen scenario 1: Doubling the Nozomi trains

Before



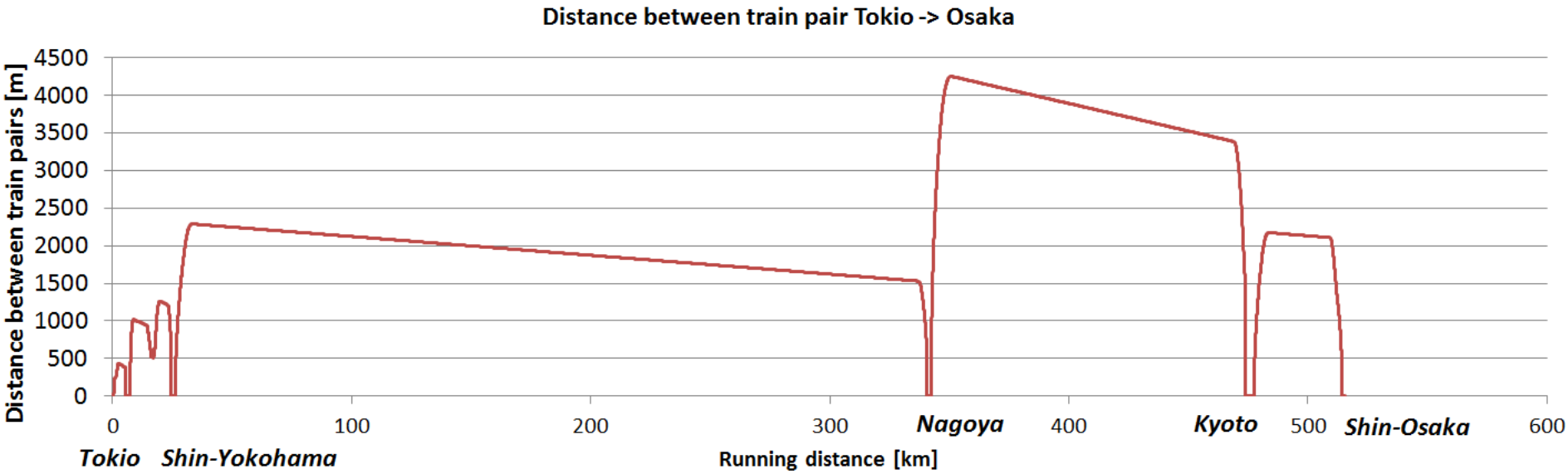
After



Shinkansen scenario 1: Doubling the Nozomi trains

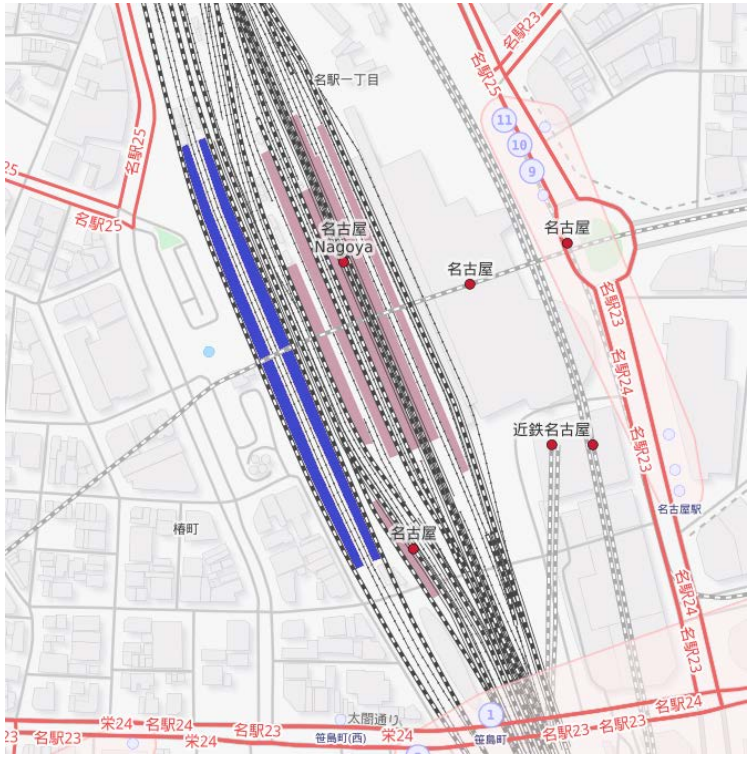
Distance between train pairs

- Developing running distance depends on distance between stopping place and switch (Nagoya > Yokohama / Kyoto)
- Distance decreases during run → second is a little bit faster (simulation detects little departure delay)

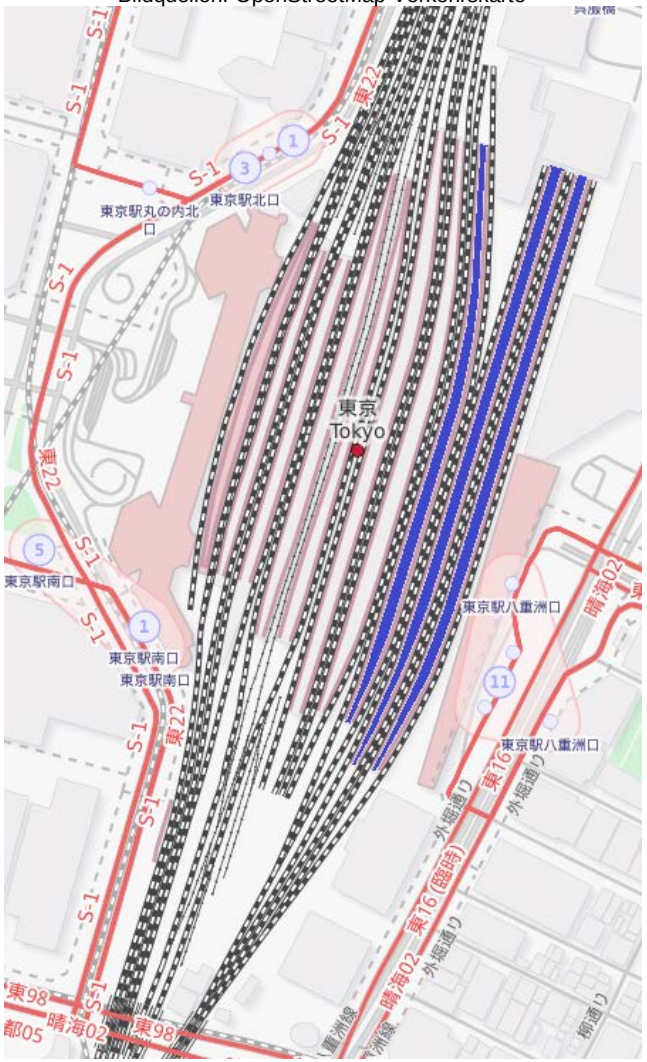


Stations Nagoya and Tokio

- Shinkansen stations have confined space conditions
- Only 2 tracks per direction in Nagoya, of which only one can be used for terminating trains

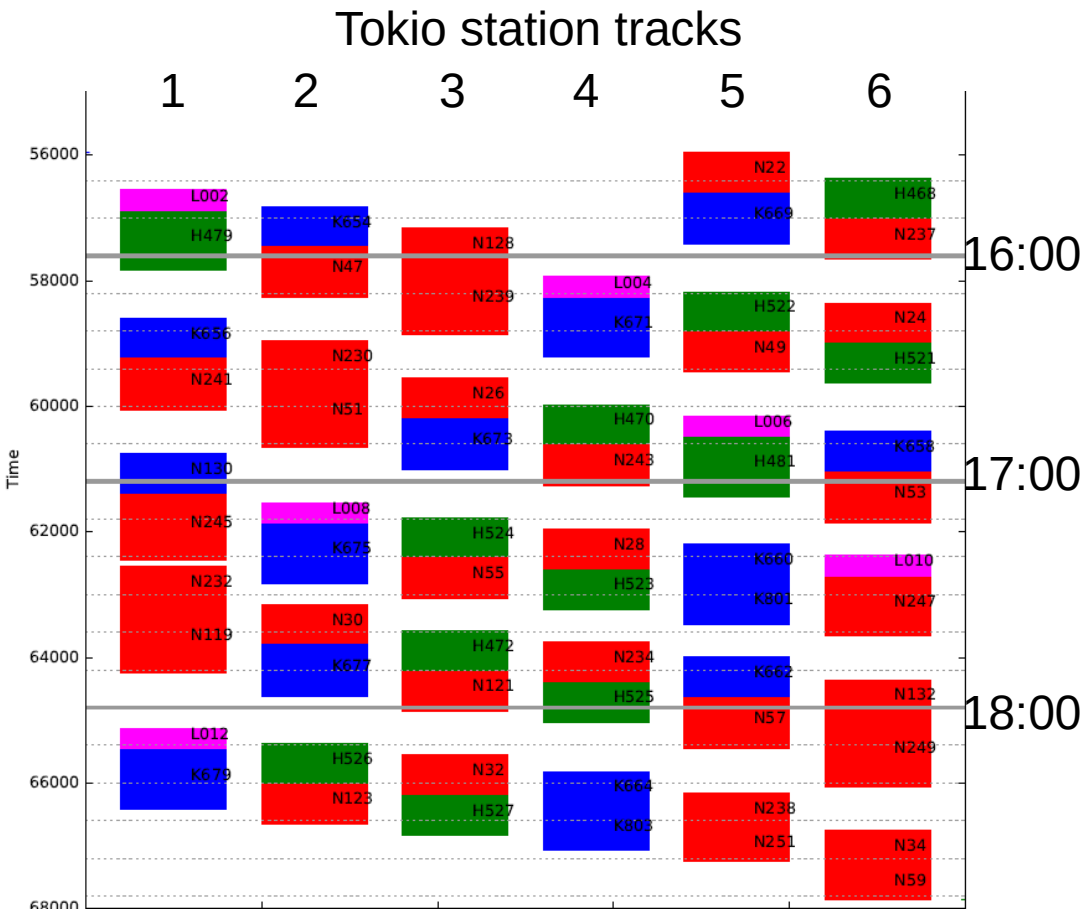


Bildquellen: OpenStreetMap Verkehrskarte

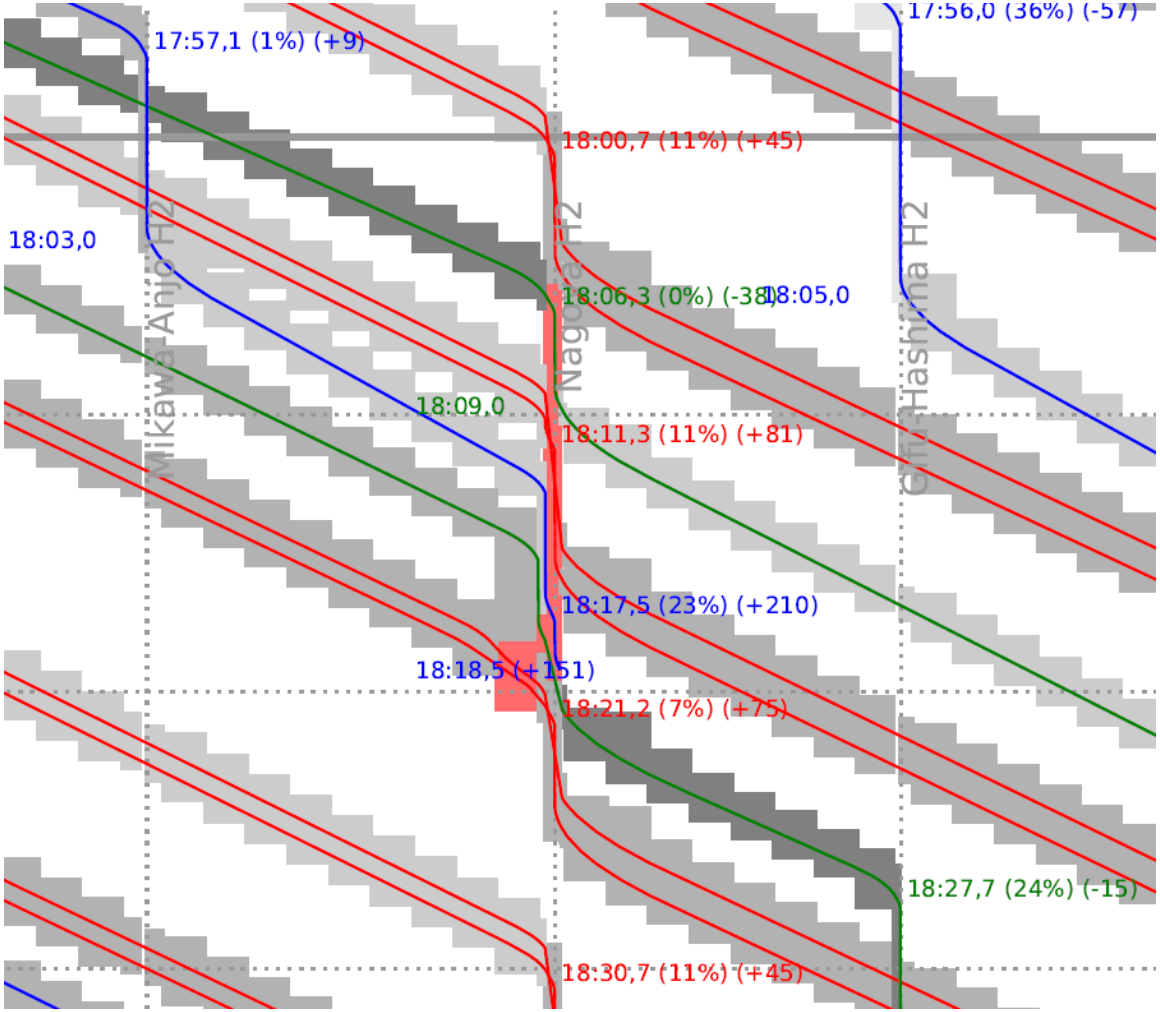


Tokio Station Track Occupation

- 6 tracks in Tokio station for Tokaido line
- Currently 12 minutes turn-around-time in average
- Accessing platform track / Door opening / Disembarking / Cleaning / Turning chairs / Boarding / Door closing / Departure / Leaving platform track
- With virtual coupling either a new platform is needed or the turn-around-time has to be shortened



Shinkansen scenario 1 – Nagoya Bottleneck



Results of the Shinkansen scenario 1

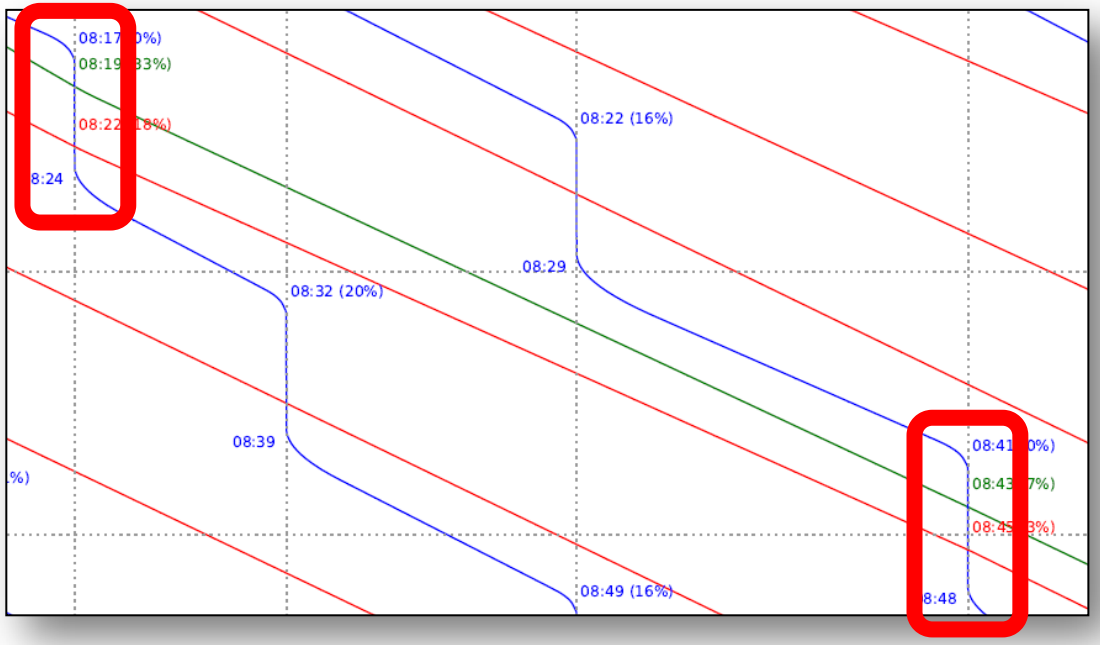
- Benefit: increase of line capacity from 15 000 to 23 000 per hour and direction
- New platforms needed in Nagoya and probably Tokio and Osaka needed

Timetable: departures at Tokio (16.00 – 19.00)	Original 2015 timetable	Shinkansen scenario 1: Doubling of Nozomi trains
Nozomi trains / h	6	12
Hikari trains / h	2	2
Kodama trains / h	3	3
Train count / h	11	17
Seat capacity / hour / direction	15 000	23 000
Train-kilometer (all)	15 494	24 780
Energy consumption (all)	271,1 MWh	426,1 MWh
Specific energy consumption (all)	17,5 kWh / train-km	17,2 kWh / train-km
Delay sum arrival (all)	0 min	242 min
Obstructions (all)	11	104

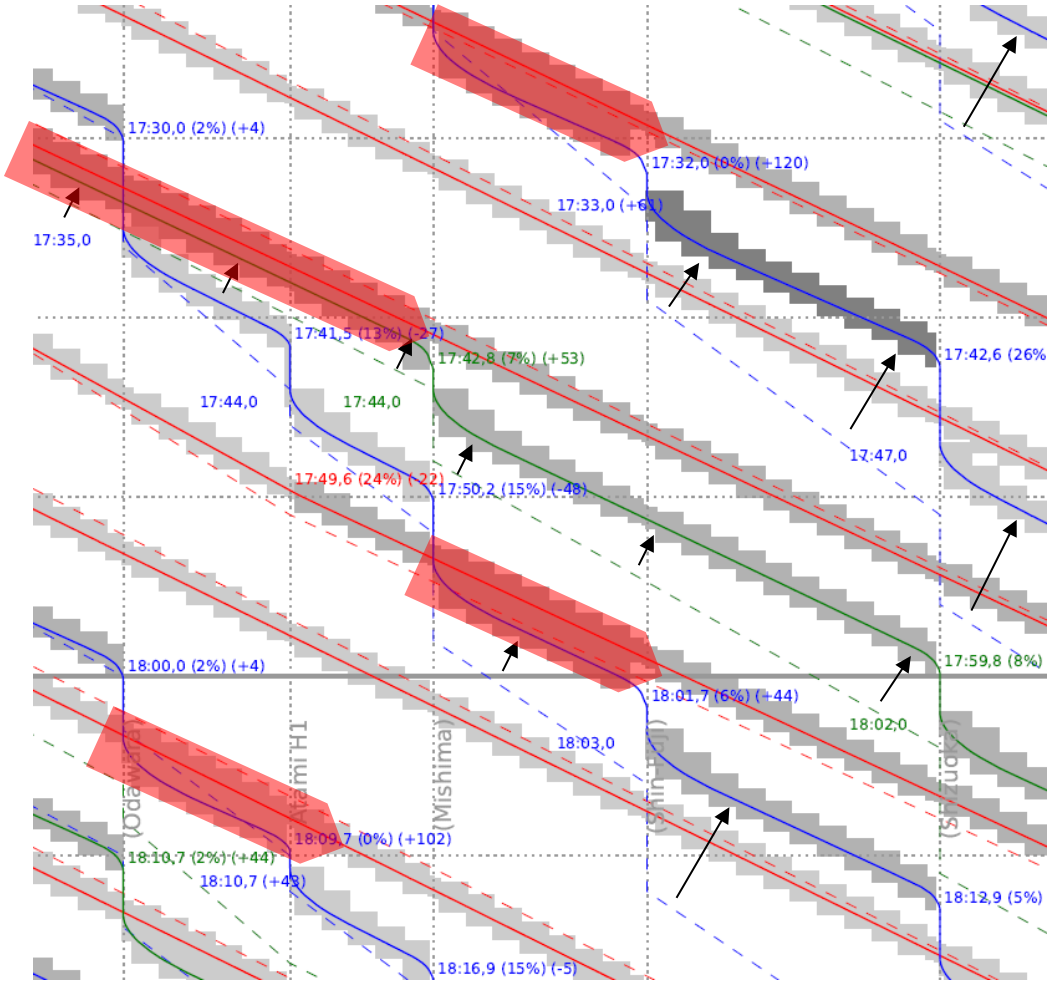
Nagoya needs new platform

Shinkansen scenario 2: Being overtaken by 2 trains

- Kodama trains are passed by other trains at every stop
- Sometimes even by two trains
- Virtual coupling of these two trains could lead to shorter stop times and thus to shorter travel times



Shinkansen scenario 2: Timetable compression



Shinkansen scenario 2: Timetable compression

- Constraints:
  - Reduction of stopping time from 3 to 2 minutes (1 min at small stations)
  - Reduction of time allowance to 3% for Kodama and Hikari trains
- Results do not meet the expectations
- Reasons:
  - Many stops of Hikari trains prevent benefits for the capacity of the line
  - Station Atami has platforms directly at the fast track
  - Getting Kodama trains one station further for overtaking is only possible by violating the minimal stopping and allowance times
  - Nagoya Bottleneck prevents increase of train numbers
- Benefit:
  - Travel time reduction of 1/3 of the trains at around 20 minutes between Tokio and Osaka

Conclusion and outlook

- Benefit of virtual coupling is limited because of the necessary **absolute braking distance to switches**
- Virtual coupling in operation looks more or less like running in relative braking distance
- Increase of line capacity is possible by doubling fast trains
  - Two platform tracks necessary at every stop
  - Additional track capacity at main stations
- Increase of capacity of Tokaido line from **15 000 to 23 000 pax / h / direction**

Outlook:

- Analysis of a **slip coaching scenario** on high-speed lines (e.g. German North-South-Line with fewer stops at Göttingen, Kassel and Fulda)
- Analysis of **freeway scenario** with the assumption not to have a switch problem

Thank you

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